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Executive Body for the Convention on Long-range Transboundary Air Pollution

Steering Body to the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe

Working Group on Effects

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Item 5 of the provisional agenda
Progress in activities of the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe and its workplan for 2024–2025
Item 9 of the provisional agenda
Progress in activities and workplan for 2024–2025 of effects-oriented activities

2023 Joint progress report on policy-relevant scientific findings

Note prepared by the Chairs of the Steering Body to the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe and the Working Group on Effects, in cooperation with the secretariat

Summary

The present report was drafted by the Extended Bureau of the Working Group on Effects[a] and the Extended Bureau of the Steering Body to the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe[b] in cooperation with the secretariat to the Convention on Long-range Transboundary Air Pollution. The review of recent scientific findings is based on the information provided by the lead countries and the programme centres of the international cooperative programmes, and is submitted in accordance with the 2022–2023 workplan for the implementation of the Convention (ECE/EB.AIR/148/Add.1).

[a] Comprising the Bureau of the Working Group; the chairs of the international cooperative programme task forces, the Joint Task Force on the Health Effects of Air Pollution; and representatives of the international cooperative programme centres.

[b] Comprising the Bureau of the Steering Body, the Chairs of the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe task forces and representatives of the Cooperative Programme's centres.

I. Introduction

1. The present report was compiled by the Chairs of the Steering Body to the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP) and the Working Group on Effects, in accordance with the 2022–2023 workplan for the implementation of the Convention on Long-range Transboundary Air Pollution (ECE/EB.AIR/148/Add.1). The report reflects achievements during 2022 and 2023 and was prepared with support from the scientific subsidiary bodies.

II. Air pollution effects on health – advancement of tools

2. The AirQ+ tool has been updated (version 2.2) based on the World Health Organization (WHO) 2021 Air Quality Guidelines. It is a user-friendly tool available in several languages that was designed for public health or environmental specialists and that allows to estimate the magnitude of the most important and best recognized impacts of air pollution in a given population. AirQ+ can also serve as an educational resource to raise awareness about air pollution.

3. The soon-to-be-released Climate Mitigation, Air Quality and Health software tool (CLIMAQ-H) is a decision aid tool for investigating carbon mitigation pathways and their health and economic benefits. The tool allows users to explore different emission reduction scenarios and their effects on air quality, health outcomes (mortality and morbidity), life expectancy and disease incidences. The results can be used to inform stakeholders, decision-makers and policymakers in formulating pragmatic and socially acceptable interventions to address climate change. The tool was applied to calculate the health co-benefits of climate policies in several countries in the European region and beyond, demonstrating benefits reaching beyond national boundaries.

4. **Air quality and health impact assessments – new calculations using Greenhouse Gas Air Pollution Interactions and Synergies (GAINS) model and methodological updates**. Key scenarios (Baseline, MTFR, LOW) were analysed assessing the impacts of different measures and feasibility of achieving ambitious targets, i.e., 50% reduction of impacts. The analysis highlighted the potential for further mitigating air pollutants and methane, particularly in Eastern Europe, Central Asia and non-European Union countries. Reductions in ambient particulate matter ($PM_{2.5}$) concentrations were projected, with the LOW scenario indicating significant improvements and potential health benefits for the majority of the European and Central Asian region by 2050. The inclusion of demographic factors, such as ageing populations, influenced the ambition level and the achievement timeline. Update was provided on the ongoing work on methods for impact assessments of air pollution, both for mortality and morbidity.

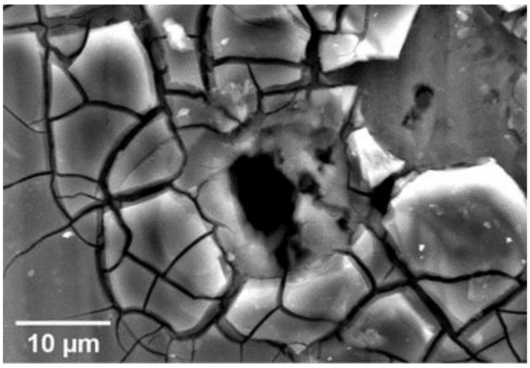
5. **Surface ozone air pollution and human health.** It is important to consider both nitrogen dioxide (NO_2) exposure and ozone (O_3) together, because of their health and ecosystem impacts in Europe. They are strongly interlinked from a chemical point of view and anticorrelated in space and time. Data showing trends in the observed O_3 levels across monitoring sites in Europe displayed variations – while O_3 annual mean concentrations increased significantly in certain areas, there was a decrease in O_3 peaks. There are several challenges in mitigating O_3 levels, for example, year-to-year and daily variability of O_3 formation and its long-range transport, and also emission reduction measures may lead to increased O_3 concentrations in cities while reducing levels outside urban areas. It is important to consider the complexity of O_3 trends, the challenges of mitigation, and the expected penalty of climate change on O_3 levels.

III. Air pollution effects on materials and the call for data on United Nations Educational, Scientific and Cultural Organization World Cultural Heritage Sites

6. The International Cooperative Programme on Effects of Air Pollution on Materials, including Historic and Cultural Monuments (ICP Materials) conducts repeated exposures for trend analysis every third year and the latest exposure concluded in 2021. All data on environment, corrosion and soiling produced to date is contained in the corresponding ICP Materials reports, which are available as PDFs for download at the home page of ICP Materials

7. When looking at observed trends, corrosion and pollution have decreased significantly since the early 1990s and a shift in the magnitude was generally observed around 1997, from a sharp decrease to a more modest decrease or to a constant level without any decrease. Particulate matter is currently the pollutant that requires the most attention; particles might play an important role for the initiation of pits in, for example, aluminium, as well as increasing soiling of materials. The figure below shows an example of a localized corrosion attack of aluminium (pit).

Initial localized corrosion (pit) of an aluminium specimen from the 4-year exposure (2017–2021) corresponding to the site in Bottrop, Germany



Source: Ms. Alice Moya Núñez, RISE Research Institutes of Sweden, Kista, Sweden

8. ICP Materials also conducts studies of selected United Nations Educational, Scientific and Cultural (UNESCO) sites and the air pollution responsible for the corrosion and soiling effects of the materials contained in monuments. In 2022, the studied monuments included: St Domnius Cathedral, Split, Croatia; Würzburg Residence, Germany; and Royal Palace, Caserta, Italy. In 2023, selected monuments in Switzerland will be evaluated. In total, about 30 monuments have been studied as part of the ICP Materials UNESCO call for data.

IV. Air pollution effects on terrestrial ecosystems

A. Forests

9. Although forest air pollution has changed significantly since the 1980s, it still has significant impacts on forest ecosystems that may be aggravated by increased pressures from climate change.

10. Air pollution, especially nitrogen (N) deposition and tropospheric O_3, continues to affect forest ecosystems. Several forest ecosystem compartments (from trees to ground vegetation, mosses and lichens, including their diversity, soil composition and soil solution) and processes (tree nutrition, tree growth, soil acidification, N and phosphorous cycling) were demonstrated to be affected by air pollution, especially N deposition. Effects of ground-level O_3 were mostly detected in terms of visible foliar injury on dozens of woody species across Europe, with other effects on tree growth and fruiting also reported. O_3 effects were modulated by a range of site and plant characteristics. Heavy metals (HMs) accumulation (especially mercury (Hg)) was obvious in mosses and soil.

11. New methods and approaches offer new opportunities to understand the mechanisms, processes and interactions among organisms by which ecosystems respond to air pollution and climate change. The role of the soil microbiome and its diversity in forest tree vitality, growth and tree nutrition is under increasing stress from air pollution and climate change and is an important topic that needs to be integrated into long-term forest monitoring and research.

12. Recent periods of drought and heat have been shown to affect tree vitality, growth, nutrition and phenology to varying degrees in different parts of Europe. In addition, several regions in Europe were hit by storms that caused devastating damage. Both disturbance factors (droughts and storms) promoted bark beetle infestations. It is likely that extreme events associated with climate change will increase in frequency and intensity, further increasing pressure on European forests. Given the ongoing pressures from various forms of air pollution and the projected increase in frequency of climate change-related events, there is an urgent need to better understand the interactions between these two factors.

13. Europe-wide, science-based monitoring remains essential to provide up-to-date information on the status and evolution of forest health, diversity and productivity. The continuous increase of scientific results coming out of the monitoring networks within the International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) is clear proof of the highly relevant nature of this system for a better understanding of the response of forests to air pollution and environmental stressors. The ICP Forests multilevel, multimedia monitoring approach is proving to be essential for assessing and modelling forest ecosystem condition and for comparison between models and measurements.

14. ICP Forests has reviewed its current strategy, with the results showing that it is still relevant and timely. However, financial resources for monitoring infrastructure and personnel are always an issue; more activities to secure the programme are highly desirable. The revised ICP Forests Strategy for the period 2024–2030 was approved by the ICP Forests Task Force at its thirty-ninth meeting (online, 6–8 June 2023).

B. Forested catchments

15. Trend analyses of concentrations of the HMs – Hg, lead (Pb) and cadmium (Cd) – in watercourses within the International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems **(**ICP Integrated Monitoring) network (and the Swedish environmental monitoring programme) were performed.[1] Over the full period of evaluation, decreasing trends in Hg were seen in 35 per cent of the watercourses, while 41 per cent showed a decreasing trend in Pb and 70 per cent a decreasing trend in Cd. The declines mostly occurred in the earlier part of the data period, from 2000–2005 for Hg, and from 2000–2015 for Pb and Cd. However, towards the end of the evaluated period, from 2015–2020, more watercourses showed significant increasing, rather than decreasing trends in Hg, Pb and Cd concentrations, and the reasons for this require further investigation and continued monitoring. The overall trends could be driven by declining deposition of HMs over Europe, but other changes may contribute, such as processes related to recovery from acidification and ongoing browning of surface waters.

16. Studies on biodiversity show that many lichen species are sensitive to air pollution and react rapidly, especially to sulfur (S) and N, and are well-established indicators of air quality. Lichen communities were adversely affected by the widespread high levels of S deposition in the 1970s and 1980s. During the last decades, there has been a rapid decline in S deposition, but less so for N. The response of epiphytic lichens to this decline was analysed, using data from long-term ICP Integrated Monitoring sites in Sweden.[2] Only limited and partial evidence of recovery was detected in the area that previously had high levels of

[1] Eklöf and others, “Trends in mercury, lead and cadmium concentrations in European streams and rivers: 2000-2020”, in preparation.

[2] James Weldon and Ulf Grandin, “Weak recovery of epiphytic lichen communities in Sweden over 20 years of rapid air pollution decline,” *The Lichenologist*, vol. 53, No. 2 (2021), pp. 203–213.

deposition. The slow recolonization of sensitive species, even where environmental conditions are now suitable, is probably a result of depleted regional species pools and the inherent very limited dispersal capacity of many lichen species. The conclusion is that lichens are less useful indicators for improved air quality than for deteriorating air quality.

17. The impact of N deposition on forest bryophyte communities was assessed using data from the ICP Integrated Monitoring and ICP Forests networks to analyse the relationship between levels of throughfall N deposition and bryophyte taxonomic and functional diversity, and community nitrogen preference.[3] The study found that N deposition is associated with increased dominance of locally common nitrophilous species. The effect sizes at currently realistic levels of deposition were modest, with stronger responses at high levels of deposition that are rarely found nowadays in Europe. However, community metrics such as these do not capture detrimental effects on individual sensitive species of concern.

V. Air pollution effects on aquatic ecosystems

18. **Biological recovery and biodiversity**. Long-term records of aquatic insects in acid-sensitive rivers and lakes in Europe showed significant increases in species richness, which is related to chemical recovery from acid deposition. The aquatic insects considered were Ephemeroptera Plecoptera Tricoptera taxa (Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies)). Many of these species are acid-sensitive and the monitoring records are of high taxonomic quality. The sites included 55 acid-sensitive rivers and lakes in Germany, Italy, Norway, Sweden, Switzerland and the United Kingdom of Great Britain and Northern Ireland. In all, 47 per cent of all rivers (21 sites, for the period 1994–2018) and 35 per cent of all lakes (34 sites, for the period 2000–2018) showed significant increases in species richness. The smaller changes for lakes compared with rivers could be related to the shorter time period, but biological communities in lakes can also be less responsive than in rivers because of lower rates of habitat recolonization.

19. **Chemical recovery and confounding factors.** Water chemical records from acid-sensitive waters in Europe and North America demonstrated responses to declining deposition of sulfur, in particular declines in sulfate concentrations. The decline in deposition leads to chemical recovery, as shown by increases in acid-neutralizing capacity and pH. In many regions, deposition of sulfate now approaches background levels and factors other than deposition, such as climate, become increasingly important for variations in surface water acidification.

20. **Review of the Protocol to Abate Acidification, Europhication and Ground-level Ozone (Gothenburg Protocol).** The contribution from the International Cooperative Programme on Assessment and Monitoring of the Effects of Air Pollution on Rivers and Lakes (ICP Waters) to the review of the Gothenburg Protocol included estimations of expected chemical recovery given EMEP deposition scenarios for 2030 and 2050 for a few selected ICP Waters sites, and a comparison of modelled and measured Acid Neutralizing Capacity. It was concluded that further reduction of S and N deposition will lead to more chemical recovery, but not to pre-acidification water chemistry. Climate change and inter-annual variability in weather will have greater effects on Acid Neutralizing Capacity as acid deposition declines, with unknown consequences for biological recovery.

21. **Open data policy.** The open data policy following Findable-Accessible-Interoperable-Reusable principles is supported by ICP Waters, and in many countries monitoring data are made publicly available already. ICP Waters is exploring tools for increased openness and access to data, such as creative common licences and data papers.

[3] James Weldon and others, "Nitrogen deposition causes eutrophication in bryophyte communities in Central and Northern European forests", *Annals of Forest Science*, vol. 79, No. 24 (2022), pp. 1–14.

VI. Critical loads and levels

A. Critical loads

22. In 2022, the Coordination Centre for Effects (CCE) of the International Cooperative Programme on Modelling and Mapping of Critical Levels and Loads and Air Pollution Effects, Risks and Trends (ICP Modelling and Mapping) published a report entitled *Review and revision of empirical Critical Loads of nitrogen for Europe*,[4] updating Empirical Critical Loads of N ($CL_{emp}N$) for the fourth time since 1992. The report reflects the results of the international cooperative process, coordinated by CCE between 2020 and 2022, to which a total of 43 authors, representing ICP Forests, ICP Integrated Monitoring, ICP Modelling and Mapping, ICP Waters and the International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops (ICP Vegetation), contributed their scientific expertise. The review was finalized with a United Nations Economic Commission for Europe (ECE) CCE expert workshop (Bern, 26–28 October 2021), hosted by the Swiss Federal Office for the Environment. The updated list of $CL_{emp}N$ contains CL values for 51 different European ecosystems. There was enough evidence to take up nine new ecosystems in the list of sensitive receptors and adapt the values for 36 receptors. Most of the revised values were lowered considering the latest scientific findings.

23. To support the review of the Gothenburg Protocol, risks of acidification and eutrophication of ecosystems have been calculated by the CCE for the European Parties to the Convention. This work was completed in close cooperation with other bodies of the Convention under the EMEP Programme, namely the Centre on Emission Inventories and Projections (CEIP), the Centre for Integrated Assessment Modelling (CIAM) and the Meteorological Synthesizing Centre-West (MSC-West). The exceedance calculations are based on the 2021 policy-relevant Critical Loads database, compiled by CCE and consisting of national CL data collected from National Focal Centres to ICP Modelling and Mapping and of data calculated with the CCE background database, for those countries that did not calculate and deliver national data.

24. For eutrophication of ecosystems, CL are exceeded in large parts of the model domain. The share of ecosystems, where the CL for eutrophication are exceeded, decreases relatively slowly, starting at 74 per cent in 2000 and going down to 61.2 per cent in 2020. The highest exceedances of CL are found in the Po Valley (Italy), the Netherlands-German and German-Danish border areas and in north-eastern Spain. The scenario analyses under the review of the Gothenburg Protocol reveal that, even under the most ambitious scenario for the year 2050, 22 per cent of European ecosystems would still be exposed to N deposition beyond CL.

25. For acidification of ecosystems, CL are exceeded only on very few parts of the receptor area. In 2000, acidity occurred on 14.1 per cent of the ecosystem area, going down to 3.6 per cent in 2020. Remaining hot spots of exceedances can be found in the Netherlands and its border areas with Germany and Belgium, and some smaller maximum in southern Germany and Czechia, whereas most of Europe is not exceeded. The scenario analyses under the review of the Gothenburg Protocol reveals a further decrease to 1 per cent of area at risk until 2050 with the most ambitious scenario.

26. The Centre for Dynamic Modelling (CDM) interviewed all ICPs to get an up-to-date overview of the ongoing dynamic modelling work within the Working Group on Effects, and potential for future collaboration and developments. Interactions between air pollution and climate change has been identified as one of the most important areas that are policy relevant and could be addressed by dynamic models. The Centre continued to develop the common Working Group on Effects website according to the concept agreed with all ICPs and the Working Group on Effects Chair. In 2022, CDM was able to organize its first-ever in-person meeting (Sitges, Spain, 6–8 April 2022). Effects of N deposition on ecosystems, modelling

[4] Roland Bobbink, Christin Loran and Hilde Tomassen, eds., Report No. 110/2022 (Dessau-Roßlau, German Environment Agency, 2022). Available at www.umweltbundesamt.de/publikationen/review-revision-of-empirical-critical-loads-of.

biodiversity change, interaction of air pollution and climate change, and modelling of impacts on soils have been identified as the most important areas for further work. The meeting also stressed the importance of observational data from monitoring and from ecosystem experiments for model applications and development.

27. Critical loads (CL) for eutrophication and acidification were calculated at ICP Integrated Monitoring sites.[5] Concentrations and fluxes of sulfate, total inorganic N (TIN) and acidity in deposition substantially decreased at the sites. Decreases in S deposition resulted in decreased concentrations and fluxes of sulfate in run-off, and decreasing trends of TIN in run-off were more common than increasing trends. The trends indicated the more effective reductions of S deposition compared to N at the sites. Sites with higher cumulative exceedance of eutrophication CL (averaged over 3 and 30 years) generally showed higher TIN concentrations in run-off. The results provided evidence of the link between CL exceedances and empirical impacts and confirm that emission abatement actions are having their intended effects on CL exceedances and ecosystem impacts.

B. Critical levels: Effects of ozone on vegetation

28. More than ten years after the recommendation of the updated Air Convention critical levels for ammonia (NH_3), new findings on the effects of NH_3 on vegetation were discussed in a workshop organized by CCE (Dessau, Germany (hybrid), 28–29 March 2022). A report on the proceedings of the workshop was published in 2023.[6] The main results of the workshop were transferred together with the comments of the experts from ICP Vegetation and ICP Modelling and Mapping to a draft revised version of the respective chapter III.2.3 on NH_3 critical levels in the Mapping Manual. The main message is that current long-term (annual mean) critical level for lichens and bryophytes, including ecosystems where lichens and bryophytes are a key part of the ecosystem integrity, of 1 µg m^{-3} and for vascular plants, of 3 µg m^{-3}, with an uncertainty range of 2–4 µg m^{-3} were confirmed with the latest literature since the last update in 2009.

29. ICP Vegetation modelled the impacts of O_3 on wheat yield in 2015 (to represent current ambient conditions), collated information on ambient O_3 concentrations including from outside the ECE region, and investigated concentration of HMs and N in mosses in Europe.

30. **Moss survey.** To ensure the continued participation of countries of Europe it was agreed at the recent Task Force meeting to transfer the coordination of the European moss survey back to the ICP Vegetation Programme Coordination Centre in the United Kingdom of Great Britain and Northern Ireland. Over 4,000 moss samples were collected in response to the 2020–2021 call for data. Some individual countries, such as North Macedonia, have found that, following implementation of technical measures to reduce emissions from mining and metallurgical activities, metal deposition to mosses was reduced compared to the previous survey. Some other countries have found increases in concentration in mosses of some particular metals, for example, several countries reported an increase in nickel concentrations compared to previous surveys. The full report is due for publication in 2024.

31. **Modelled impacts of ambient O_3 on wheat.** Analysis of production loss of wheat for the year 2015 was carried out using the O_3 metrics Phytotoxic Ozone Dose above an ozone flux threshold of 3 nmol m^{-2} s^{-1} (POD_3IAM) and Accumulated dose of ozone Over a Threshold of 40 parts per billion (ppb) (AOT40), based on the EMEP 0.1 degree grid. POD_3IAM and AOT40 were obtained from the EMEP model (version 4.45). The results differ depending on whether AOT40 or POD_3IAM is used as the O_3 metric, however, POD_3IAM is the preferred metric as this represents the amount of O_3 entering the vegetation

[5] Martin Forsius and others, “Assessing critical load exceedances and ecosystem impacts of anthropogenic nitrogen and sulphur deposition at unmanaged forested catchments in Europe”, *Science of the Total Environment*, vol. 753 (2021), p. 141791.

[6] Jürgen Franzaring and Julia Kösler, *Review of internationally proposed critical levels for ammonia: Proceedings of an expert workshop held in Dessau and online on 28/29 March*, Report No. 31/2023 (Dessau-Roßlau, German Environment Agency, 2023). Available at www.umweltbundesamt.de/publikationen/review-of-internationally-proposed-critical-levels.

and causing damage, rather than the concentration in the air. O_3 uptake has been shown to better represent the risk to vegetation across Europe rather than concentration-based metrics such as AOT40.

32. The AOT40 metric shows that the highest percentage losses to wheat yield for 2015 were predominantly in northern Italy and central Spain, with high percentage losses across much of central Europe. However, when basing the assessment on the preferred metric POD1AM, which calculates the amount of O_3 entering a plant by taking into account local meteorological conditions, then the area and magnitude of percentage yield loss increases considerably. The regions most affected by high O_3 fluxes include much of the major wheat growing areas. This means that the highest production losses (which take into account both O_3 uptake and the amount of wheat grown) are in (in descending order) the Russian Federation, France, Ukraine, Germany, Türkiye, the United Kingdom of Great Britain and Northern Ireland, Poland, Romania, Italy and Spain. The wheat production losses from these countries alone was calculated at >18 000 tons in 2015.

33. **O_3 impacts outside the ECE region.** As part of the outreach work, diffusion tubes to monitor ambient O_3 concentration have been deployed by local scientists at several sites including in Ecuador, Ghana, Kenya, Malawi and Zambia. At some sites, such as a forest restoration site in Malawi, O_3 concentrations were likely high enough to cause reductions in plant growth, including at forest restoration sites. In Brazil average O_3 concentrations were 30–35 ppb without a clear difference between plantation type (eucalyptus v. mixed forest). These concentrations are anticipated to give negative effects on growth, photosynthesis and carbon sequestration.

34. **Impacts of NO_x on vegetation.** ICP Vegetation have carried out a literature review on the impact of NO_x on vegetation. The air pollution mix has changed since data were collected to set the critical levels for NO_x, as, at that time, concentrations of sulfur dioxide (SO_2) and $PM_{2.5}$ were much higher than now, whereas NO_x, NH_3 and non-methane volatile organic compounds (NMVOCs) concentrations were broadly similar to current concentrations. NO_x impacts are anticipated to be larger at current SO_2 concentrations than those concentrations that were considered “ambient” in the 1970s and 1980s, when the current critical levels were established. There is evidence that lichen communities in northern Europe and the United States of America respond at much lower NO_x concentrations than the current critical level, although disentangling from N deposition effects can be difficult, particularly when looking at impacts over long-term timescales.

VII. Emissions

A. Improving emission inventories

1. General Issues

35. The updated Guidelines for Reporting Emissions and Projections Data under the Convention on Long-range Transboundary Air Pollution (ECE/EB.AIR/GE.1/2022/20−ECE/EB.AIR/WG.1/2022/13) were formally adopted by the EMEP Steering Body and the Working Group on Effects during the eighth joint session (Geneva, 12–16 September 2022) and by the Executive Body during its forty second session (Geneva, 12–16 December 2022, decision 2022/1 (ECE/EB.AIR/150/Add.1)) for application in 2024 and subsequent years.

36. The Executive Body also welcomed and took note of the updated Technical Guidance for Emissions Inventory Adjustments under the Amended Gothenburg Protocol, approved by the EMEP Steering Body and the Working Group on Effects during the eighth joint session (ECE/EB.AIR/GE.1/2022/21–ECE/EB.AIR/WG.1/2022/14). The Technical Guidance aims to support Parties wishing to apply for adjustments within an emission reduction commitment framework. It outlines both best practice in quantifying adjustments within an emissions reduction commitment framework and the information that should be reported to support the technical review of the application.

37. The updated *EMEP/EEA air pollutant emission inventory guidebook 2023*: *Technical guidance to prepare national emission inventories* (EMEP/EEA Guidebook) will be available later this year. The EMEP/EEA Guidebook includes several updates and improvements in the sectoral chapters (energy, industrial processes and product use, waste, agriculture and spatial mapping) and in the general guidance, to better represent current scientific knowledge, and in particular to present the uncertainty of the information included in the combustion and industry chapters with greater transparency. This new updated version of the EMEP/EEA Guidebook benefited from the support of the European Environment Agency (EEA) and its European Topic Centre on Air Pollution, Transport, Noise and Industrial Pollution and from the contributions of several national experts. The next update should take place in 2026 or 2027 and is expected to involve more significant changes to methodologies and guidance.

2. Gridded emissions used for modelling

38. In recent years, CEIP has developed and improved a gridding system with a resolution of 0.1° x 0.1° longitude/latitude, which uses different spatial proxies for the spatial disaggregation of gap-filled data at the Gridding Nomenclature for Reporting (GNFR14) sector level. The Centre prepared gridded data of main pollutants (NO_x, NMVOCs, NH_3, sulfur oxides (SO_x), carbon monoxide (CO), particulate matter ($PM_{2.5}$, PM_{10}, coarse PM) and black carbon (BC) for the time series 2000–2021. Gridded data for HMs (Cd, Hg and Pb) and persistent organic pollutants (POPs) (Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, dioxins and furans, hexachlorobenzene) were prepared for the year 2021.

39. For the compilation of the gridded data sets, the Centre took stock of numerous data sources, beyond reported national emissions: data from the European Pollutant Release and Transfer Register reporting, especially for Large Point Sources, shipping emission data gathered by the Finnish Meteorological Institute, the Emissions Database for Global Atmospheric Research v5.0[7] built up by the European Commission Joint Research Centre, and expert estimates from CIAM and the Netherlands Organization for Applied Scientific Research. This gap-filling work still requires high levels of resources despite the semi-automatic gap-filling system developed by CEIP. There are still several Parties that do not report gridded data. Furthermore, there are quality issues with reported gridded data and documentation of the methodologies used to prepare the gridded data sets is frequently found to be untransparent. Cooperation between Parties and EMEP centres and task forces with the aim of improving the gridded data sets should be developed.

3. Reduction of NH_3 emissions

40. In 2023, eight Parties to the amended Gothenburg Protocol were not compliant with their NH_3 emission reduction commitments for 2020 for the year 2021. Emission reduction commitments under the Gothenburg protocol are applicable for 2020 and beyond. Thus, NH_3 is the pollutant regarding which most Parties of the Gothenburg Protocol have a problem in terms of being compliant. Agriculture is the sector mainly responsible for NH_3 emissions. As a first step to make progress in this area, a better understanding of the emission sources is required, which includes collection of more detailed farm-level data. In addition, a better understanding of environmental risks associated with NH_3 emissions above the agreed emission reduction commitments is required.

B. Applications for adjustments to emission inventories

41. Four previously approved adjustment applications have been assessed by the Expert Review Team in 2023 and have been imported into the website tool, where all information can easily be viewed and compared.[8] Recommendations to the EMEP Steering Body are

7 See https://edgar.jrc.ec.europa.eu/overview.php?v=431.
8 See https://webdab01.umweltbundesamt.at/cgi-bin/adj_v2.pl.

provided in the report on review of adjustment applications (ECE/EB.AIR/GE.1/2023/INF.6−ECE/EB.AIR/WG.1/2023/INF.6).

VIII. Monitoring and modelling

A. Lessons learned from the last Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe field campaign

42. The Intensive Measurement Period organized in July 2022 focused on improving the understanding of high O_3 episodes by strengthening VOC precursors monitoring. A dozen States parties contributed to the experiment, which led to the collection of an unprecedented data set. While a few EMEP stations are currently reporting VOC monitoring to EMEP, the field campaign allowed for expansion towards a much wider set of compounds, over more stations and States parties, and higher temporal frequency. It is expected that evaluations of the results from the Intensive Measurement Period will continue into the next workplan period (2024–2025), also possibly feeding a multi-model intercomparison exercise.

B. Updated Greenhouse Gas Air Pollution Interactions and Synergies model

43. The updated GAINS model is fit to be used in policy preparations. However, the quality of modelling results remains highly dependent on the quality of data reported by countries (e.g., on emissions, air quality polices adopted and implemented). The GAINS model is more comprehensive than ever. It includes the impacts of climate and energy measures on air quality and can zoom in from the continental to the city level. Urban concentrations of air pollution are to a large extend influenced by sources outside the city, often even from sources in other countries. It has been shown that measures are needed at all political and geographical levels to meet WHO Air Quality Guideline values everywhere. The Task Force on Integrated Assessment Modelling (TFIAM) will develop and present a number of policy scenarios to the policy bodies of the Air Convention, especially as a follow-up to the Gothenburg Protocol review: (a) scenarios aimed at a 50 per cent reduction of air quality-related health impacts; (b) scenarios aimed at the protection (of, e.g., 30 per cent) of N-sensitive ecosystems; and (c) scenarios that illustrate the impact of successive (staged) sectoral control policies. The need for alternative scenarios will have to be discussed further with policymakers.

C. National integrated assessment studies

44. For national integrated assessment studies there is overall consistency with the GAINS analyses. However, the inclusion of climate and energy measures in the current policy scenario differs among Parties. Several climate and energy measures involve lower emissions of NO_x and PM. But some measures could lead to an increase in emissions, such as wood burning. The impacts of emerging measures, such as carbon (C) capture and storage, or the use of hydrogen and NH_3 as an energy carrier would require additional attention from the integrated assessment community.

45. Further methodological discussions with the national experts will involve the various ways mortality and morbidity impacts are modelled. Also, further discussion is needed on the different ways to include bias corrections in future projections. Bias corrections are currently required to improve the correlation between modelled and measured air quality at local stations.

D. Other items relevant to measurement and modelling

46. The benefit of including condensable in PM emission inventories is also being assessed, in particular by making the best use of available source apportionment observations to validate the benefit for modelling results. The progress in the Eurodelta-BaP modelling intercomparison was impaired by the limited interaction with the Meteorological Synthesizing Centre-East (MSC-East), but the progress will also be presented at the next Task Force meeting. Several of these items will be followed up in the next biannual workplan, adding also a focus on monitoring chemicals of emerging concern (CECs) and contributing to the guidance on the use of low-cost sensors for air quality monitoring. A workshop on CECs is tentatively planned to be held in Norway in October 2023. This will initiate discussion of guidelines for sampling and analysing these components.

IX. Linking the scales

A. Hemispheric transport of air pollution

47. Under the current work plan 2022–2023, the Task Force on Hemispheric Transport of Air Pollution (TFHTAP) has made three key contributions: updating global emissions estimates; demonstrating tagging approaches for long-range source attribution; and contributing to the review of the revised Gothenburg Protocol. The updated global emissions mosaic, HTAPv3, is a timeseries for 2000–2018 for O_3 precursors and PM components and precursors. It was developed from global and regional emissions data sets through the cooperation of the European Commission Joint Research Centre and a number of national and regional partners. O_3 precursor tagging has been used to estimate the contribution of global Hg emissions sources to local O_3 concentrations and to demonstrate that maritime shipping emissions on the high seas, as well as in coastal waters, contribute to the long-range transport of O_3. The Task Force’s previous multi-model intercomparisons, along with findings from other cooperative global atmospheric chemistry studies in the literature, provided a basis for describing trends in the influence of sources outside the ECE region on pollutants covered by the revised Gothenburg Protocol.

48. TFHTAP is currently planning three multi-model intercomparison exercises related to: the impact of international policies on Hg; future global policy scenarios’ impact on Gothenburg Protocol pollutants; and the influence of wildfires and agricultural burning on multiple pollutants. The first phase of the Hg exercise, referred to as the Multi-Compartment Hg Modelling and Analysis Project, is being planned as a contribution to the Minamata Convention on Mercury first effectiveness evaluation and will begin in the second half of 2023. The assessment of the impacts of future global policy scenarios on Gothenburg Protocol pollutants will include a focus on understanding the effect of global Hg controls on ground-level O_3 impacts. Engaging with the global chemical transport and chemistry-climate modelling communities, this work is expected to begin in 2024, with initial results expected in 2025. The fires assessment is in the early planning stages and seeks to compare modelled estimates of the impact of wildfires and agricultural burning on fine particles, O_3, POPs, Hg and other metals. In cooperation with the Biomass Burning Uncertainty: ReactioNs, Emissions and Dynamics (BBURNED) activity of the International Global Atmospheric Chemistry research network, the Task Force will co-host a virtual workshop on global fire emissions inventories in November 2023.

B. Expert Panel on Clean Air in Cities

49. Measurements and modelling studies show that a range of different sectors contribute to air pollution, such as traffic, industry, residential heating and agriculture. These sectors contribute differently to the air pollution in different cities in the European Union, the Western Balkans and countries of Eastern Europe, the Caucasus and Central Asia. Local urban sources from traffic and residential heating contribute most to the NO_2 pollution in large cities, while industrial and agricultural sources from outside the city contribute most to

PM_{10} and $PM_{2.5}$. Models provide the necessary information for local and national authorities for decisions related to air quality in combination with other policies, such as those on spatial planning, energy and climate.

50. Multilevel governance is necessary for achieving the health objectives (both from an efficiency and an equity perspective). Also, integrating policies is important; N and climate policies are important to meet air quality objectives, while the air quality objectives are also relevant for climate policies.

51. Positive actions to improve air quality have been demonstrated for several cities, such as London, Paris and Berlin, and countries, such as the Netherlands. These can serve as examples for other cities and regions. It was demonstrated that attention to communication and raising awareness of the local air quality is important. Citizen science is a powerful research and policymaking approach in support of cleaner air, providing data, awareness and actions. It is important to integrate citizen science into research and governance to achieve the zero pollution goals.

X. Methane

52. Hg is a tropospheric O_3 precursor and a short-lived climate pollutant that is often co-emitted with NH_3 emissions from agriculture. The discussions of the Saltsjöbaden VII Workshop (Gothenburg, Sweden, 13–15 March 2023) indicated that high priority should be given to understanding the Hg/O_3 problem and to finding national strategies for Hg emission reductions. As a first step, national positions on how to best achieve emission reductions and a better understanding of the practicalities and processes required for including Hg emissions in annual emissions inventory reporting are required in the coming years.

53. According to a survey conducted by the Task Force on Emission Inventories and Projections (TFEIP) in 2023 among inventory compilers and modelers, many experts believe Hg is a priority issue to be addressed by the EMEP Steering Body. Initial indications from modellers are that, if Hg emissions were included in the Air Convention, then they would not need gridded Hg emissions data for their modelling purposes. If this is the case, then emissions data reported to the United Nations Framework Convention on Climate Change (UNFCCC) could be used without significant additional processing (although there may be some minor issues associated with linking the UNFCCC common reporting format structure with the Air Convention Nomenclature for Reporting).

54. A multi-model experiment downscaling global Hg mitigation scenarios over Europe was conducted in collaboration with the Copernicus Atmosphere Monitoring Service, and further discussed with TFHTAP in order to derive a consensus diagnostic on the benefit of Hg mitigation, not only for background hemispheric O_3 as widely documented through global scale modelling work, but also for peaks in high exposure areas of Europe. This work is complemented with similar modelling work being undertaken by MSC-West on the basis of recent CIAM scenarios.

XI. Reorganization and relocation of the Meteorological Synthesizing Centre-East activities

55. During its forty-second session (Geneva, 12–16 December 2022), the Executive Body for the Air Convention noted and discussed the uncertainty regarding the feasibility of financing and implementation of the activities to be carried out in 2023 by the EMEP technical center MSC-East,[9] in the circumstances referred to in General Assembly resolution ES-11/1 on aggression against Ukraine.[10] Thus, it requested the EMEP Steering Body (EMEP SB) "to assess options for reorganization and relocation of the activities currently implemented by the centre, with due consideration for the need to retain geographical

[9] Note that the EMEP Meteorological Synthesizing Centre-East (MSC-East) is hosted in Moscow by an organization which has the same name, MSC-East

[10] A/RES/ES-11/1.

balance, and to report back on that assessment to the Executive Body at its forty-third session”. [11]

56. The Chair and Vice-Chairs of the EMEP Steering Body, with the support of the joint Extended Bureaux of the EMEP Steering Body and the Working Group on Effects, carried out consultations with various stakeholders and analysed potential options, which are presented in the document Reorganization and relocation of the Meteorological Synthesizing Centre-East activities: review of the options by the Steering Body to the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (ECE/EB.AIR/GE.1/2023/7–ECE/EB.AIR/WG.1/2023/7). This document will be discussed at the ninth joint EMEP Steering Body/Working Group on Effects session and the resulting proposal will be forwarded for consideration by the Executive Body at its forty-third session (Geneva, 11–14 December 2023).

[11] ECE/EB.AIR/150 (advance version), para. 37 (c).